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NRL Memorandum Report 183

COPY NO. 49

PERFORMANCE OF A "HEARING AID" TYPE AMPLIFIER AS A CRYSTAL VIDEO RECEIVER

R. D. Mayo

RADIO DIVISION II

15 June 1953

NAVAL RESEARCH LABORATORY
Washington, D.C.

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PERFORMANCE OF
A "HEARING AID" TYPE AMPLIFIER
AS A CRYSTAL VIDEO RECEIVER

by

R. D. Mayo

15 June 1953

Countermeasures Branch
Radio Division II
Naval Research Laboratory
Washington 25, D. C.

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ABSTRACT

The performance of the M-1 "Hearing Aid" amplifier (PYE LTD Radio Works of Cambridge, England) as a crystal-video receiver is examined and compared with the AN/ULR-3 receiver for both video and r-f sensitivity. It is found that the M-1 when equipped with a crystal detector, external bias supply, and horn antenna, can be used to intercept any pulse-modulated signal within the frequency band of the antenna. Its circuitry and small size result in a sacrifice in sensitivity against signals with time-durations less than 10 microseconds or pulse repetition frequencies less than about 500 pulses-per-second. Recommendations are made for the improvement of the sensitivity for signals of shorter pulse time duration and lower pulse repetition frequency.

PROBLEM STATUS

This is an interim report; work is continuing on this problem.

AUTHORIZATION

Conf Ltr from BuShips to NRL C.A22 (701) Ser C-701-4092/45 dtd 7 Dec 45
NRL Problem 39R06-07
RDB Number NR 506-070

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PERFORMANCE OF A "HEARING AID" TYPE AMPLIFIER AS A CRYSTAL VIDEO RECEIVER

INTRODUCTION

It is the purpose of this report first, to discuss the use of the M-1 "hearing aid" amplifier (manufactured by PYE LTD Cambridge, England) as a crystal-video receiver, second, to compare its capabilities with those of the AN/ULR-3 crystal-video receiver (developed at this Laboratory about two years ago), and third, to suggest methods of improving the utility of the M-1 amplifier as a crystal-video receiver.

The AN/ULR-3 crystal-video receiver was selected for a comparison with the M-1 Amplifier because the AN/ULR-3 was the receiver nearest in function and design to the M-1 amplifier.

A crystal-video receiver consists essentially of a crystal detector followed by a high-gain video amplifier. The crystal detector is usually located at or near the antenna and provides direct detection of all amplitude-modulated signals. Since the crystal-video receiver is untuned (i.e. possesses no selectivity) the r-f bandwidth of the receiving system is limited by the antenna with which the receiver is used. The sensitivity of the receiver to pulse-modulated signals (such as radar) depends, among other things, upon the bandwidth of the video amplifier. The shorter the pulses the greater is the video bandwidth required for optimum sensitivity. For example, the optimum video bandwidth for a one microsecond pulse is about 700 kc.

Due to the extremely compact packaging and the plastic encapsulation technique employed on the M-1 amplifier, it has been impossible to separate the amplifier into several parts to measure and evaluate each individually. For this reason it has been possible to examine only the over-all performance and merits of the amplifier.

GENERAL DESCRIPTION OF THE M-1 AMPLIFIER

The M-1 amplifier is a miniature, battery-powered, hearing-aid type amplifier for use in amplifying either audio or video signals. The outside plastic case measures about 5 inches long, 3 inches wide and 1 inch thick and the entire amplifier weighs less than one pound. The amplifier has a single ear phone used by an operator for monitoring the audio output. The amplifier along with the ear phone, input cable and junction box is shown in Figure 1. The junction box is not a part of the M-1 amplifier but was constructed so that a standard coaxial cable with BNC connectors could be used between the input lead (shielded) and the signal source (or antenna).

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Figure 2 shows the amplifier with its battery compartment open. The batteries required by the amplifier are a 22½ volt "B" battery (Eveready No. 412E or an equivalent) and a 1½ volt "A" battery (Eveready No. 1016 or an equivalent).

The schematic diagram of the amplifier is shown in Figure 3 and the physical layout of the components can be seen from the X-ray picture in Figure 4. The M-1 amplifier is encapsulated in a plastic material so that the only way to view the physical layout is by means of X-rays.

PERFORMANCE OF THE M-1 AMPLIFIER

In examining the performance of the M-1 amplifier it was necessary to determine the maximum gain, the bandwidth, and the manner in which the video sensitivity varied for changes in both input pulse length and pulse repetition frequency. The maximum over-all gain is about 80 db and this can be seen in Figure 5. The bandwidth (over which the gain is not down more than 3 db from the maximum) is from 2 kc to 14.5 kc.

Video sensitivity of the M-1 was determined by measuring the input pulse amplitude required to just produce a minimum detectable audio signal in the output of the M-1. All the video sensitivities were measured by the same operator and are subjective because they depend upon the particular hearing characteristics of the operator. Thus, the results of these tests are qualitative although it has been found that similar tests, conducted by a number of operators who have what might be considered normal hearing, give results which do not differ appreciably.

It was determined that the video sensitivity of the M-1 amplifier decreased as the pulse time duration became shorter and the pulse repetition frequency became less. This can be seen from the curves of Figure 6. The reduction in sensitivity with pulses of shorter time duration is due to the fact that, with the limited bandwidth of the M-1 amplifier, the amplifier rise-time is not sufficient to allow the signal within the amplifier to reach maximum amplitude before the end of the input pulse. The curves of Figure 6 for the three time durations show clearly that the sensitivity of the M-1 is greater for the pulses with higher pulse repetition frequencies. This can be explained by the fact that the average input power increases directly with pulse repetition frequency of the signal. The frequency characteristics of the ear phone, the amplifier, and the operator's ear combine to reduce the measured sensitivity of the M-1 for signals of a low pulse repetition frequency.

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COMPARISON OF THE M-1 AMPLIFIER AND THE AN/ULR-3 CRYSTAL-VIDEO RECEIVER

General Description of the AN/ULR-3 Receiver

The AN/ULR-3 is a portable, crystal-video receiver designed primarily for the detection of radar-type signals and operates on 115 volt, 60 cycle power. Figures 7, 8, and 9 are photographs showing a view of the front panel, top, and bottom respectively of the AN/ULR-3. It is portable since its weight is only about 7 pounds and its external dimensions are 7 inches high, 8 inches wide, and 6 inches deep from front to back. In operation, the receiver is connected through a 12-foot power cord to a 60-cycle supply of 115 volts and it consummes about 28 watts.

The receiver is of the crystal-video type since it is normally preceded by a silicon crystal which detects the r-f pulse-modulated signals intercepted by the antenna. The AN/ULR-3 receiver is wide-open in frequency since it responds to any amplitude-modulated signal in the frequency band covered by the antenna with which the receiver is used. The demodulated pulses from the detector are amplified by the video amplifier section of the receiver (V101, 102, and 103 of Figure 10). The maximum gain of the amplifier is 104 db and the bandwidth (within which the gain is not down more than 3 db from maximum) is from 20 kc to 750 kc. The amplified pulses are then stretched to effectively increase their average power and they are then applied through an output-matching transformer to a pair of high-fidelity, 600 ohm headphones for aural monitoring by an operator. The pulse stretcher consists of a 1N52 germanium diode (CR101) with a high back-resistance, a 500 micromicrofarad capacitor (C110), and a one megohm resistor (R125). The 500 μμf capacitor charges in less than 1 microsecond through the low impedance charging path provided by the cathode-follower circuit of V103. The 500 μμf capacitor discharges through the relatively high resistance path provided by R125 and the back resistance of the diode in parallel. The time constant for this network is of the order of 150 microseconds.

The AN/ULR-3 receiver contains an internal source of forward biasing current (40 microamperes) for the detector crystal. This bias current provides improved sensitivity and a reduction in sensitivity variations from crystal to crystal.

Figure 11 shows two horn antennas, the larger one is for S-Band (2.3 kmc to 5 kmc) and the smaller one is used for X-Band (5 kmc to 11 kmc). The beamwidth of the S-Band horn antenna between half-power points is 50° in the H-plane and about 110° in the E-plane, at a frequency of 3000 mc. The X-Band horn antenna has appreciably higher gain than the S-Band antenna and the half-power beamwidth of the X-Band horn at a frequency of 9000 mc is 36° in the E-plane and 41° in the H-plane. These two antennas are designed so that a d-c return path is provided for the crystal detectors.

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The X-Band horn has a built-in crystal holder, while the S-Band horn requires an external holder such as the Polytechnic Research and Development Co. type 613 coaxial crystal-mount. Construction details for horns which are similar to those of Figure 11, can be found in Figures 12, 13, 14, 15, and 16. Type 1N23B crystals are generally used since they are somewhat more sensitive in the X-Band region and only a slight amount less sensitive in the S-Band frequency region than the 1N32 or the 1N21B types. By using the 1N23B crystals for both frequency bands there are fewer operating and spare parts required.

Video Sensitivity Comparison of the AN/ULR-3 and the M-1

It was found that the AN/ULR-3 in general was more sensitive than the M-1, particularly for pulses of short time duration and low pulse repetition frequency. It can be seen from an examination of the curves of Figure 17, how the video sensitivities of the M-1 and the AN/ULR-3 compared over a range of pulse repetition frequency and for three values of pulse time duration. The dotted curves in Figure 17 are the same curves as are shown in Figure 6 for the performance of the M-1 amplifier, and they are discussed in more detail earlier in this report. An examination of the curves of Figure 17 will disclose the fact that the AN/ULR-3 video sensitivity was affected less over the range of pulse repetition frequencies (prf) than was the video sensitivity of the M-1. The power applied to the headphones is proportional to the rms voltage from the pulse stretcher in the AN/ULR-3 and this voltage changes less over the range of prf than the rms voltage from the relatively unstretched pulses of the M-1 amplifier. The variation of video sensitivity with different pulse time durations for the AN/ULR-3 is much less than that for the M-1 amplifier because the greater bandwidth of the AN/ULR-3 provides a much faster rise-time and this in turn provides amplification of shorter pulses without loss in sensitivity. For a pulse time duration of 10 microseconds, and a repetition frequency of 1250 cycles per second, the sensitivities of the M-1 and the AN/ULR-3 are approximately equal.

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R-F Sensitivity Comparison of the AN/ULR-3 and the M-1

The S-Band horn antenna of Figure 11 was used alternately with the M-1 and the AN/ULR-3 amplifiers so that a comparison of r-f sensitivities could be obtained. Using the same 1N23B crystal with each receiver the sensitivities were measured against a pulse-modulated signal of 3000 mc with a pulse duration of approximately 1.0 microsecond and a pulse repetition frequency of 1000 pulses per second. The input in db below one milliwatt was observed which would just barely give a detectable output for each receiver. The AN/ULR-3 was about 15 db more sensitive than the M-1 for the particular 1N23B crystal used. An external bias supply was then connected at the input of the M-1 amplifier so as to supply the detector crystal with about 40 microamperes of forward biasing current. The sensitivity increase resulting from this application of bias was about 3 db, leaving about 12 db difference between the r-f sensitivity of the AN/ULR-3 and the M-1 for the signal characteristics mentioned above. This 12 db is the difference in r-f sensitivity of the two equipments with a non-linear (square-law) detector crystal in the circuit. The 12 db difference in the r-f input actually results in a 24 db difference in the video inputs because of the square-law action of the crystal detector. From the curves of Figure 17 (for the signal conditions of 1 microsecond pulse length and 1000 pulses-per-second) it can be seen that there is a 22 db difference in the input voltages required for minimum detectable signal in the AN/ULR-3 receiver and the M-1 amplifier. This is considered substantial agreement for measurements of this type.

RECOMMENDATIONS FOR IMPROVING THE PERFORMANCE OF THE M-1 FOR CRYSTAL VIDEO USE

It is recommended that:

1. A crystal bias supply be added to the M-1, preferably internal, such as the R108, R109 bleeder arrangement in the AN/ULR-3, to improve the sensitivity of the detector crystals and to reduce the differences in sensitivity from crystal to crystal. Better than average 1N23B crystals may be improved in sensitivity by about 1 to 3 db while average crystals may be improved as much as 2 to 6 db.

2. The video bandwidth (3 db) be increased to about 700 kc for optimum sensitivity against pulses of about one microsecond duration. This can only be done by redesign of the video amplifier portion of the amplifier and necessitates the use of more tubes.

3. Means be provided for stretching the video output from the video amplifier prior to amplifying it in the audio output stage which will increase the sensitivity for reception of low prf signals. This stretching circuit must necessarily charge through a low impedance in order to completely charge within the time-duration of the signal, or there will be a loss in the amplitude of the output signal.

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4. A coaxial type input connector be provided to replace the present connector in order to permit the use of a low-capacitance video cable between the antenna and the amplifier. The capacitance of the 22-inch lead provided with the M-1 amplifier measured 100 micromicrofarads which is as much capacitance as found in 10 feet of low-capacitance video cable.

It is obvious that a redesign of this unit as indicated above, in order to modify its characteristics, would result in a somewhat larger and heavier amplifier. Additional tubes and battery power would be required.

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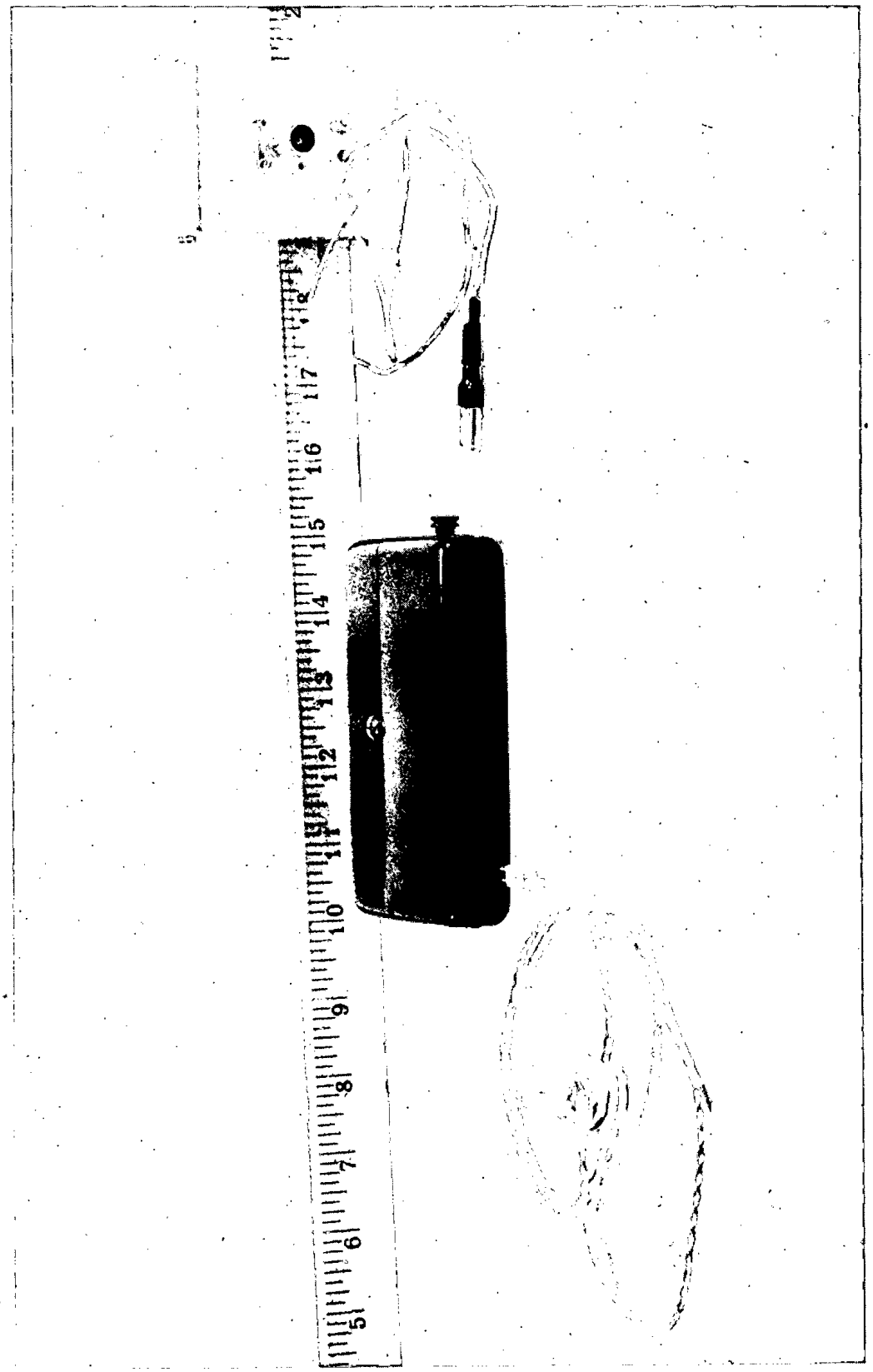

Figure 1

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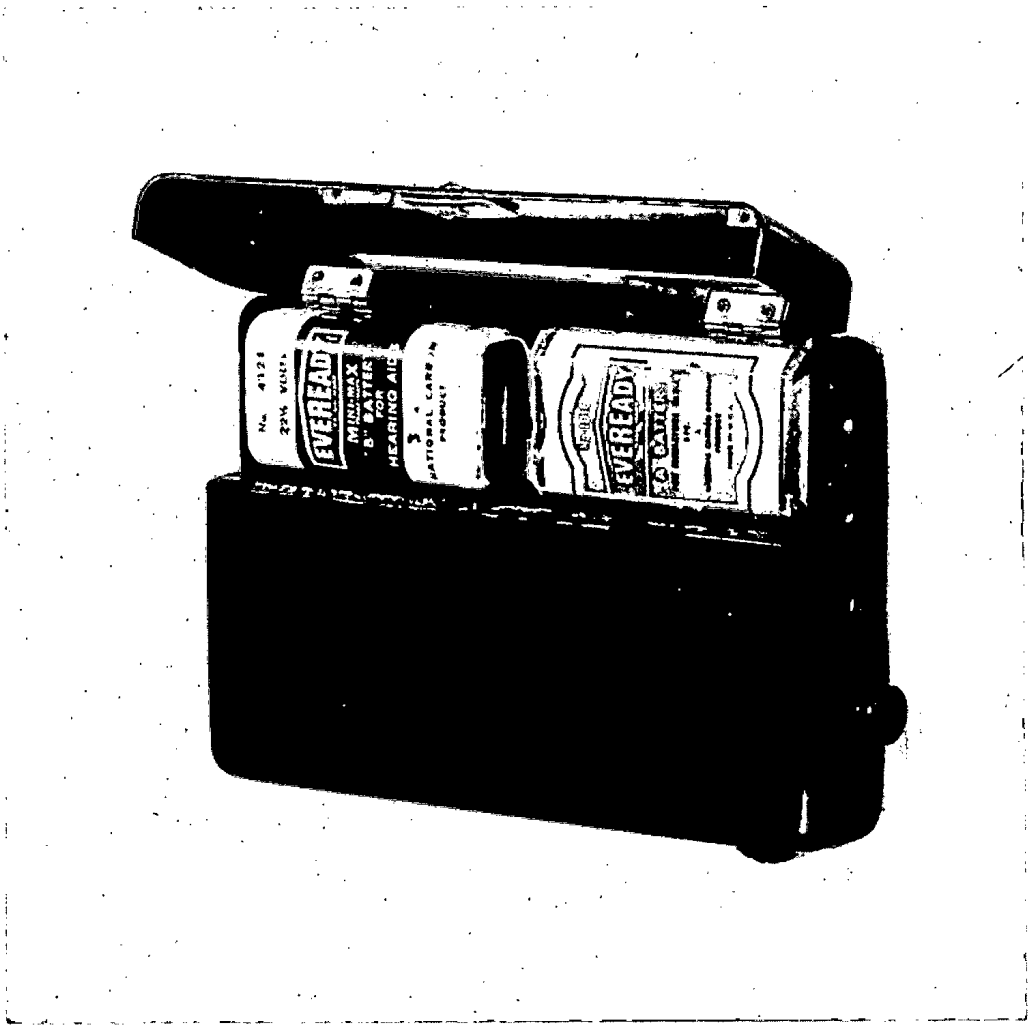

Figure 2

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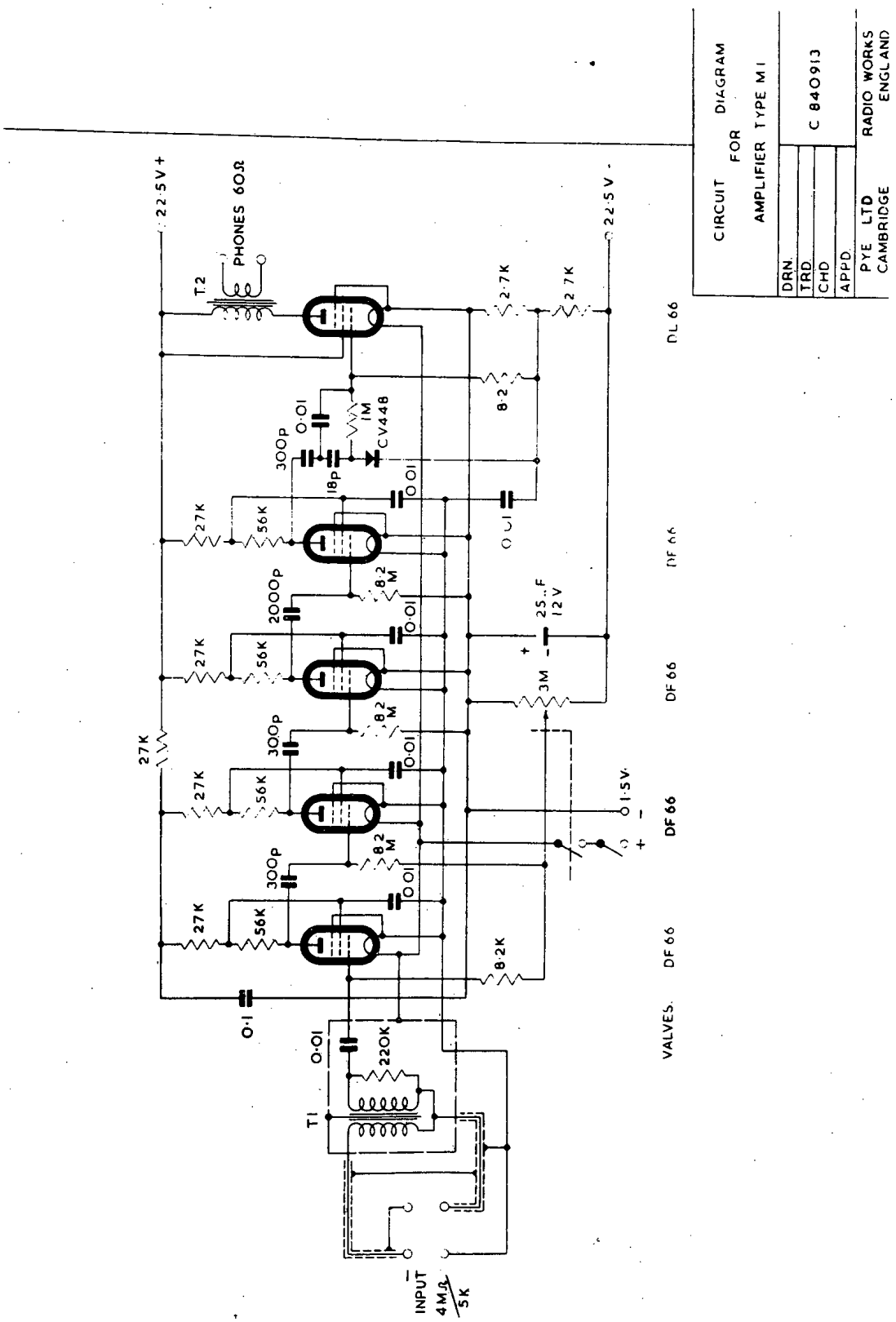

Figure 3

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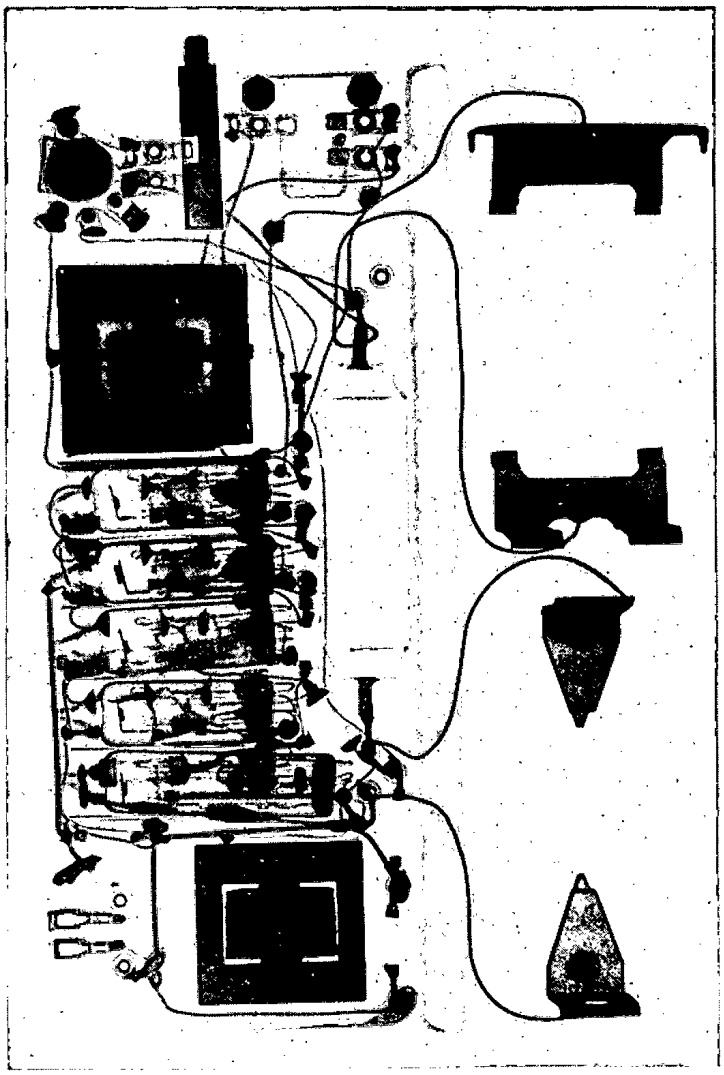

Figure 4

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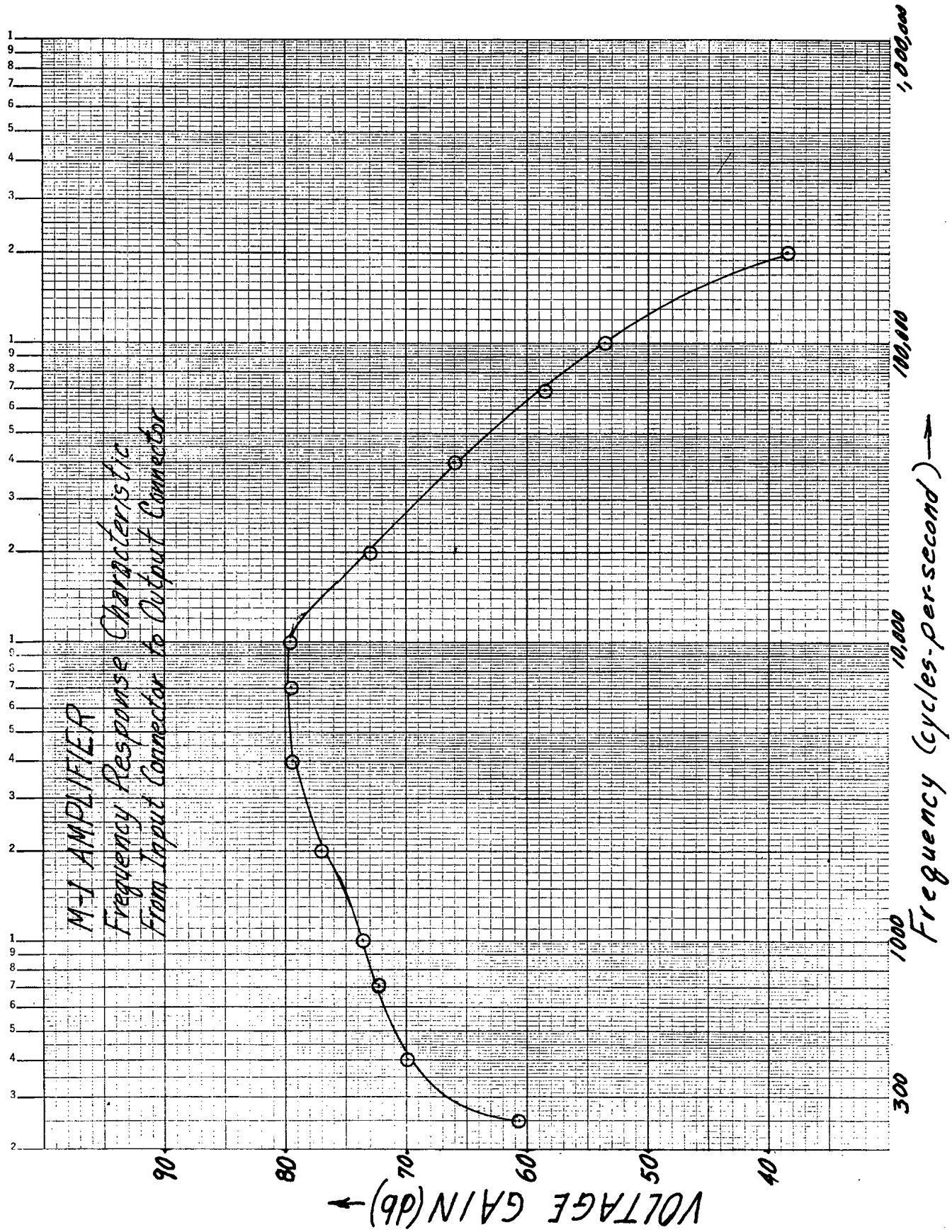

Figure 5

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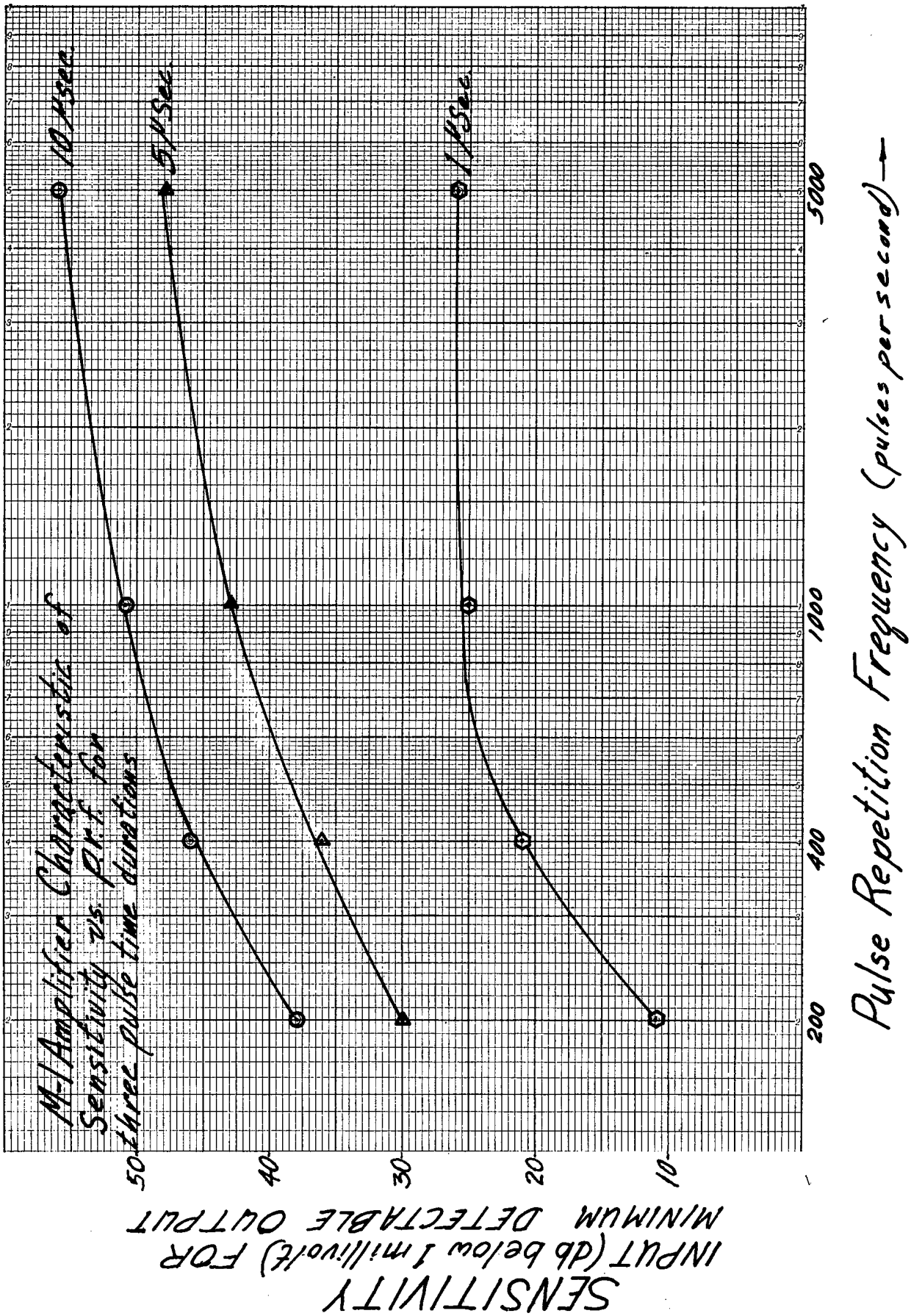

Figure 6

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Declassified in Part - Sanitized Copy Approved for Release 2013/07/31 : CIA-RDP78-03535A000500050001-9

Figure 7

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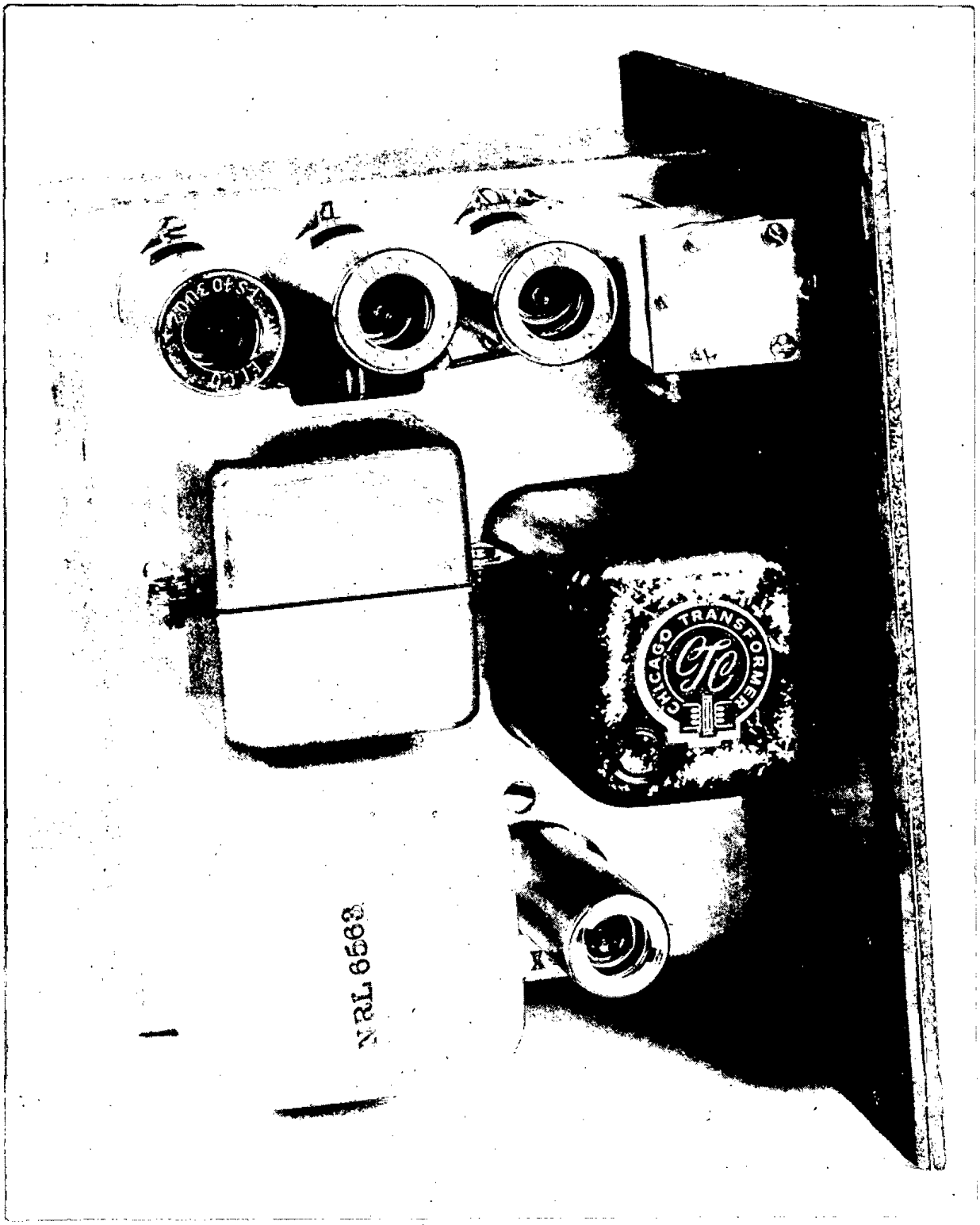

Figure 8

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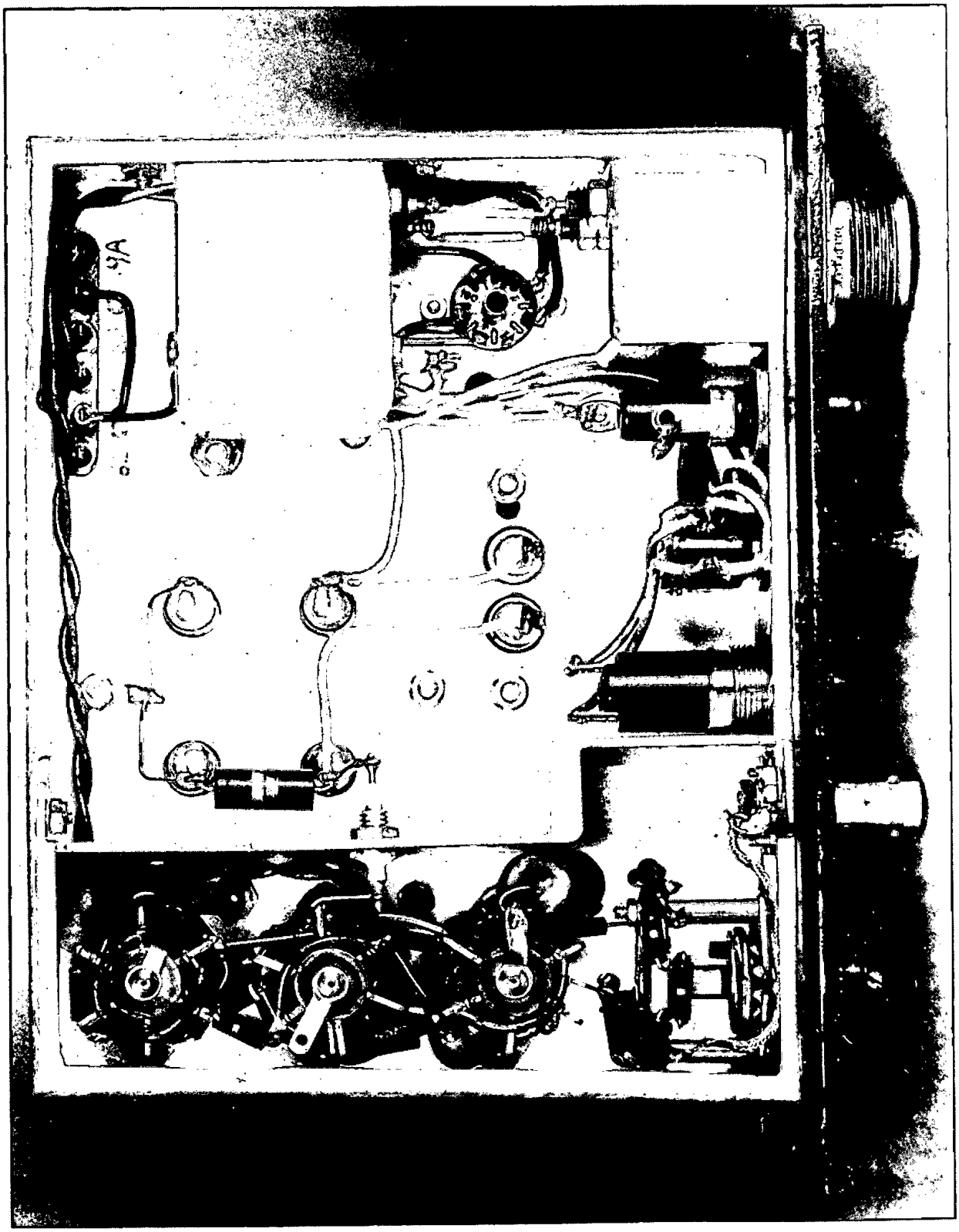

Figure 9

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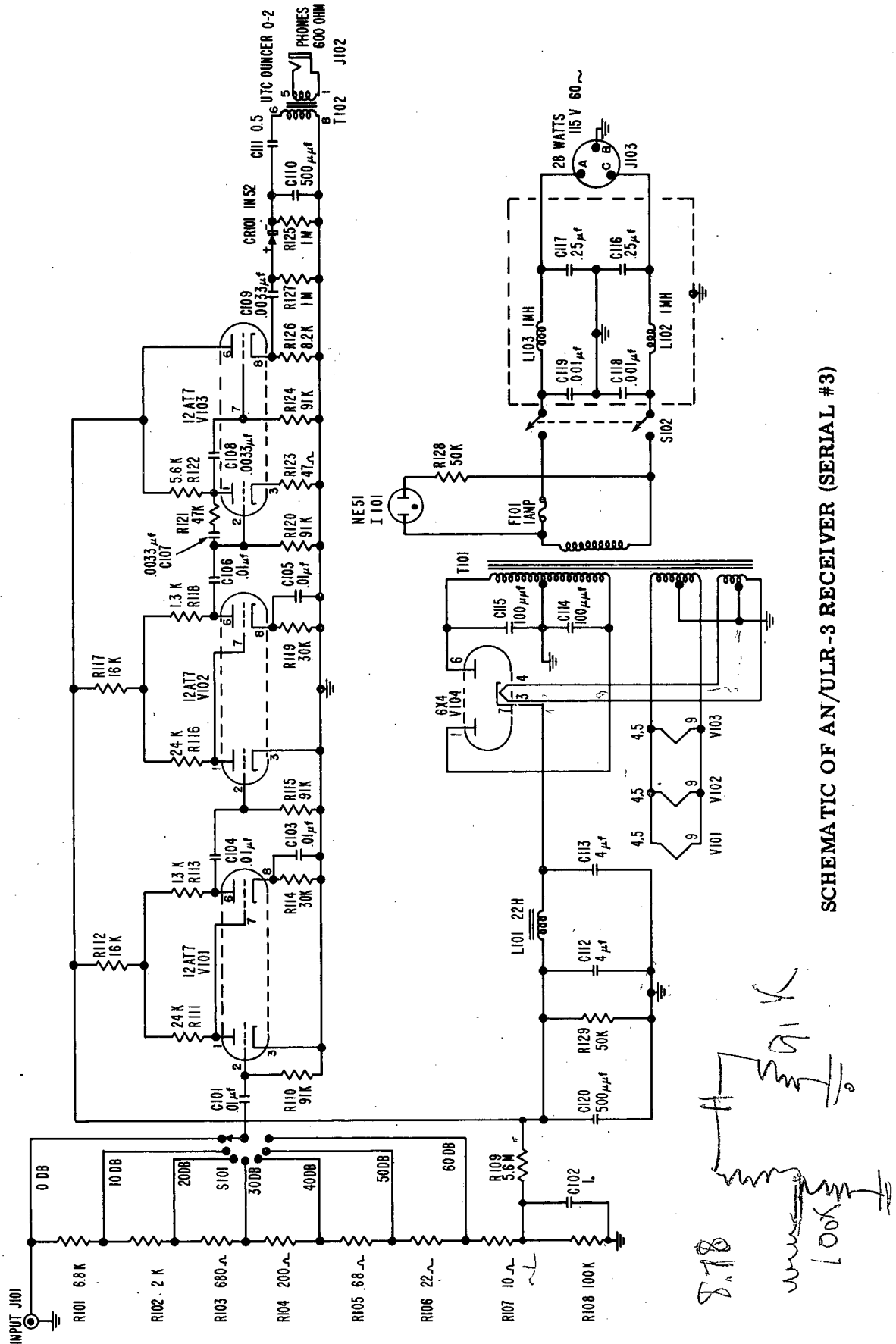

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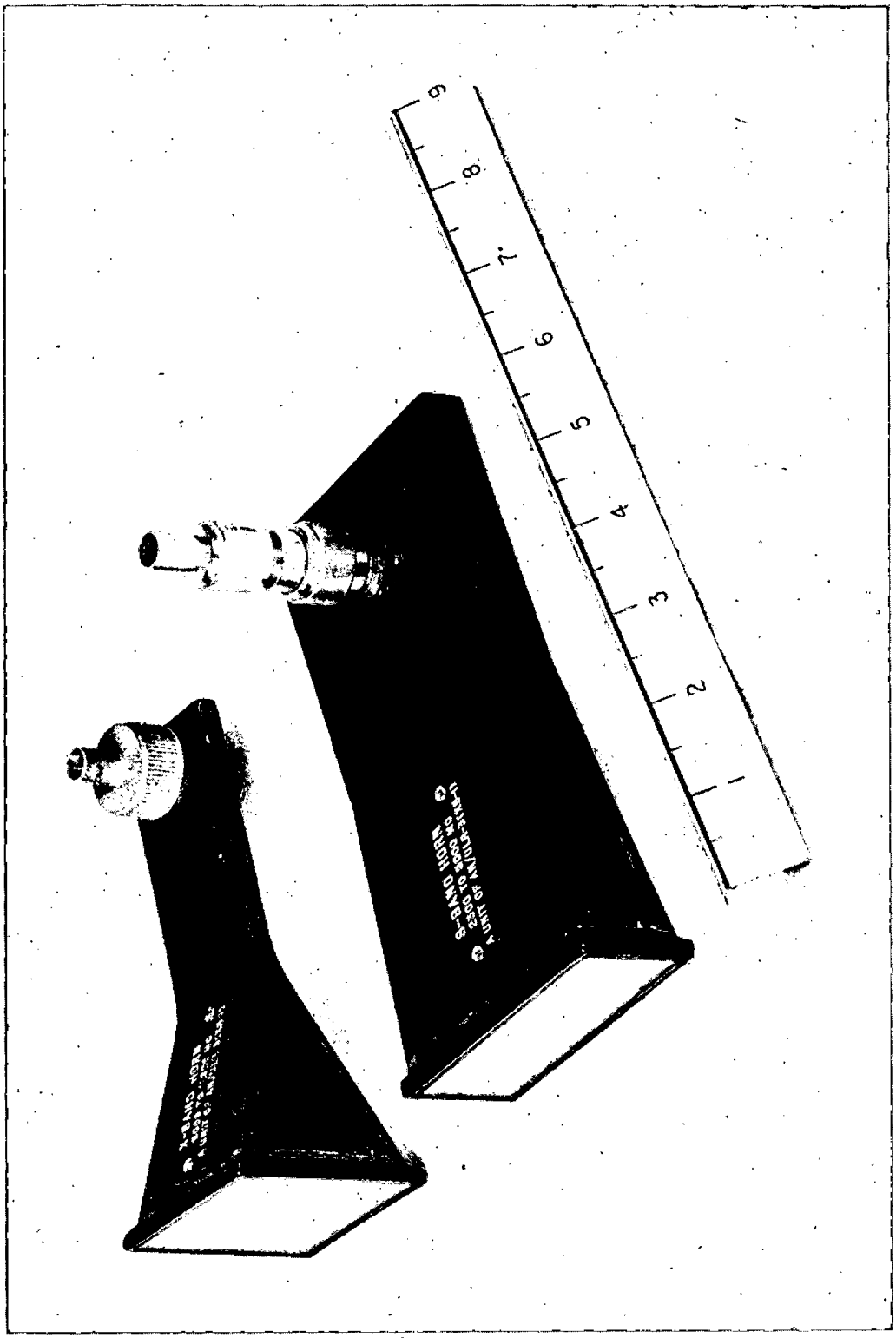

Figure 11

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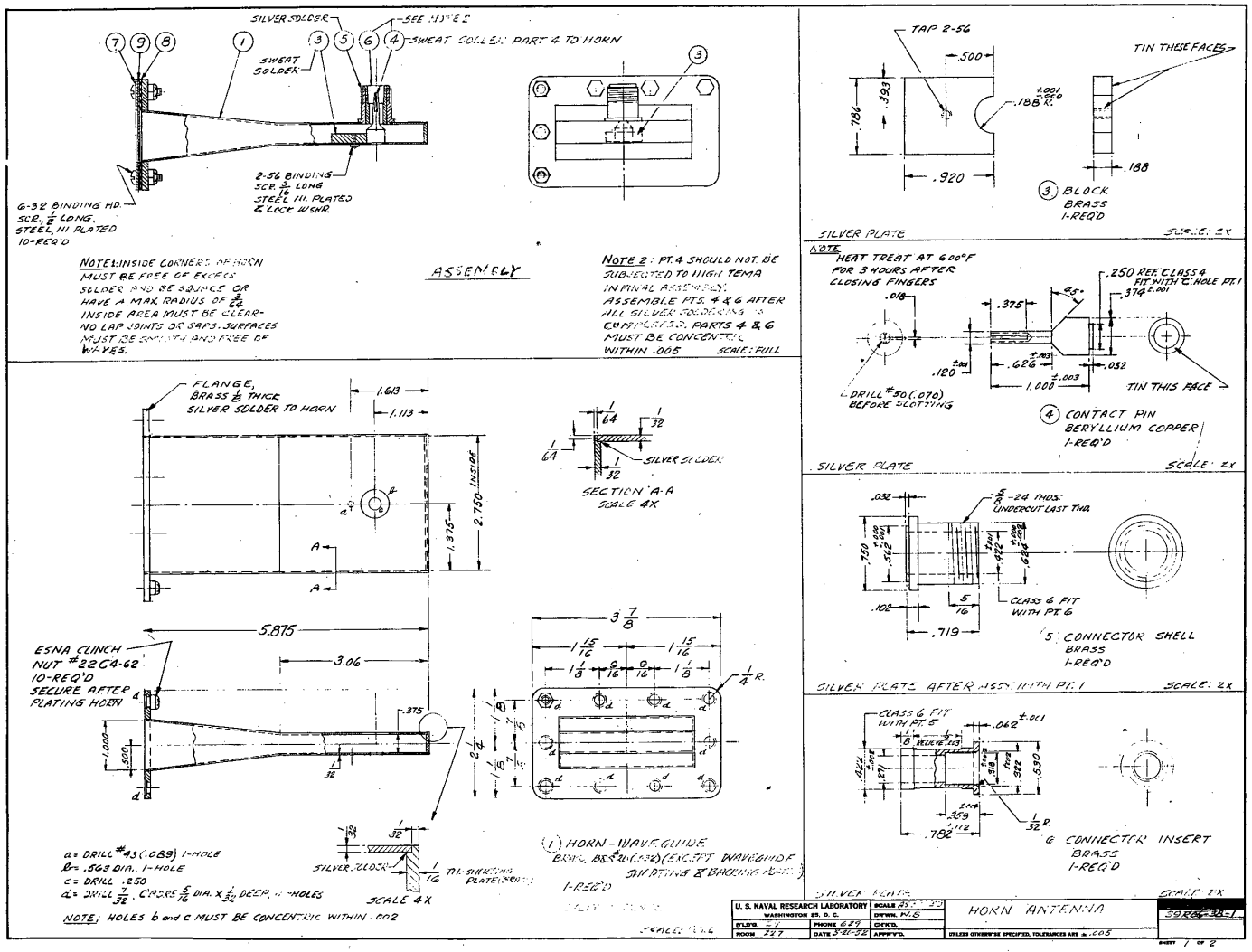

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Figure 12

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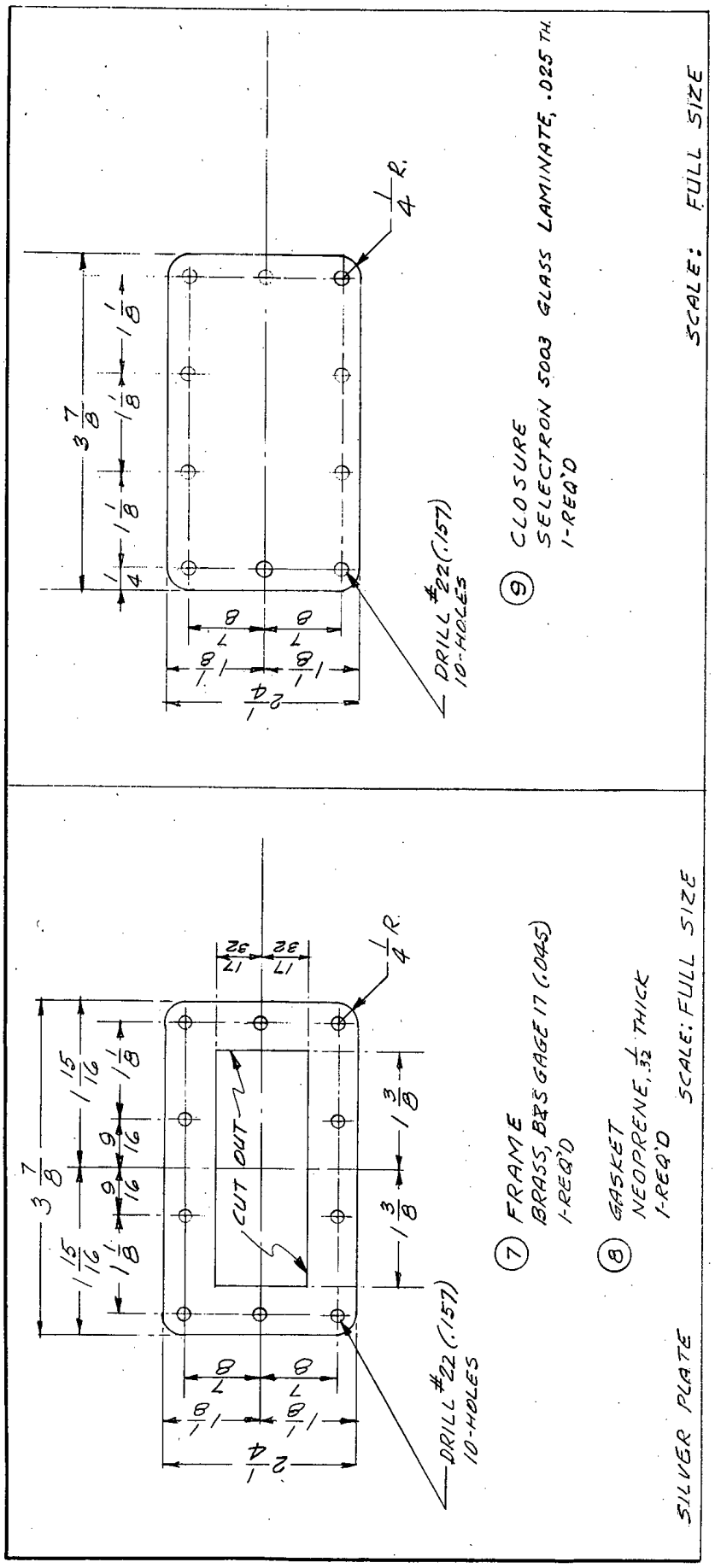

Figure 13

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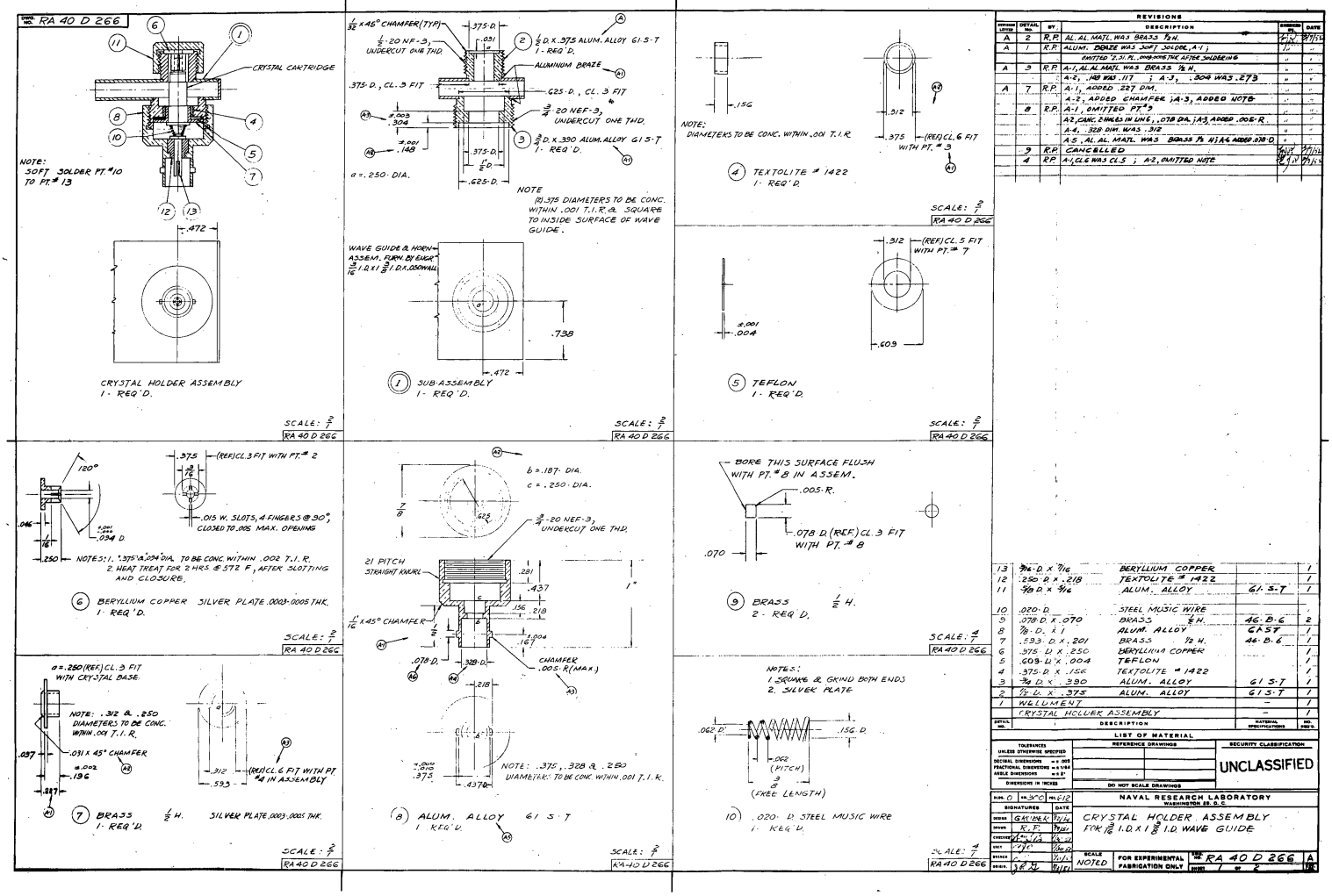
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.375 D., CL. 3 FIT
.625 D., CL. 3 FIT
3/8 - 20 NEF - 3, UNDERCUT ONE THD.
.304 +.003
.148 +.001
.375 D.
1/2 D.
.625 D.
a = .250 DIA.
1/2 D. X .375 ALUM. ALLOY 61 S-T 1 - REQ'D.
ALUMINUM BRAZE
3/4 D. X .390 ALUM. ALLOY 61 S-T 1 - REQ'D.
NOTE (R) .375 DIAMETERS TO BE CONC. WITHIN .001 T.I.R. & SQUARE TO INSIDE SURFACE OF WAVE GUIDE.
WAVE GUIDE & HORN ASSEM. FURN. BY EIMAC 3/16 I.D. X 3/8 I.D. X .050 WALL
.738
.472
(1) SUB-ASSEMBLY 1 - REQ'D.
SCALE: 2/1
RA 40 D 266
.15G
NOTE: DIAMETERS TO BE CONC. WITHIN .001 T.I.R.
.312
.375
(REF) CL. 6 FIT WITH PT.# 3
(4) TEXTOLITE # 1422 1 - REQ'D.
SCALE: 2/1
RA 40 D 266
.312
(REF) CL. 3 FIT WITH PT.# 7
+.001 .004
.609
(5) TEFLON 1 - REQ'D.
SCALE: 2/1
RA 40 D 266
120°
.375
(REF) CL. 3 FIT WITH PT.# 2
.015 W. SLOTS, 4 FINGERS @ 90°, CLOSED TO .005 MAX. OPENING
+.001 .004 D.
.046
.250
NOTES: 1. .375 & .234 DIA. TO BE CONC WITHIN .002 T.I.R. 2. HEAT TREAT FOR 2 HRS. @ 572 F, AFTER SLOTTING AND CLOSURE.
(6) BERYLLIUM COPPER SILVER PLATE .0003-.0005 THK. 1 - REQ'D.
SCALE: 2/1
RA 40 D 266
b = .187 DIA.
c = .250 DIA.
7/8
.625
3/4 - 20 NEF - 3, UNDERCUT ONE THD.
21 PITCH STRAIGHT KNURL
1"
.281
.437
.156
.218
1/16 X 45° CHAMFER
.078 D.
.328 D.
.004
.161
CHAMFER .005 R (MAX.)
.218
.375
.437D
NOTE: .375, .328 & .250 DIAMETERS TO BE CONC. WITHIN .001 T.I.R.
(8) ALUM. ALLOY 61 S-T 1 - REQ'D.
SCALE: 2/1
RA 40 D 266
BORE THIS SURFACE FLUSH WITH PT.# 8 IN ASSEM.
.005 R.
.078 D (REF) CL. 3 FIT WITH PT.# 8
.070
(9) BRASS 1/2 H. 2 - REQ'D.
SCALE: 4/1
RA 40 D 266
NOTES: 1. GRUMME & GRIND BOTH ENDS 2. SILVER PLATE
.062 D.
.156 D.
.062 (PITCH)
3/8 (FREE LENGTH)
(10) .020 D. STEEL MUSIC WIRE 1 - REQ'D.
SCALE: 4/1
RA 40 D 266
a = .250 (REF) CL. 3 FIT WITH CRYSTAL BASE.
NOTE: .312 & .250 DIAMETERS TO BE CONC. WITHIN .001 T.I.R.
.097
.031 X 45° CHAMFER
+.002 .196
.447
.312
.593
(REF) CL. 6 FIT WITH PT.# 4 IN ASSEMBLY
(7) BRASS 1/2 H. SILVER PLATE .0003-.0005 THK. 1 - REQ'D.
SCALE: 2/1
RA 40 D 266
REVISIONS
LETTER | DETAIL NO. | BY | DESCRIPTION | DATE
A | 2 | R.P. | AL. AL. MATL. WAS BRASS 1/2 H. | 7/24 9/11/62
A | 1 | R.P. | ALUM. BRAZE WAS SOFT SOLDER, A-1; OMITTED "2.31 K..0003-.0005 THK AFTER SOLDERING | 7/24 "
A | 3 | R.P. | A-1, AL. AL. MATL. WAS BRASS 1/2 H. | "
A-2, .148 WAS .117 ; A-3, .304 WAS .273 | "
A | 7 | R.P. | A-1, ADDED .227 DIM. | "
A-2, ADDED CHAMFER 1A-3, ADDED NOTE | "
B | R.P. | A-1, OMITTED PT.# 3 | "
A-2, CANC. 2 HOLES IN LINE, .078 DIA. 1A-3 ADDED .005 R. | "
A-4, .328 DIM. WAS .312 | "
A-5, AL. AL. MATL. WAS BRASS 1/2 H 1A-4 ADDED .078 D | "
9 | R.P. | CANCELLED | 9/11 9/11/62
4 | R.P. | A-1, CL 6 WAS CL 5 ; A-2, OMITTED NOTE | 9/11 9/11/62
LIST OF MATERIAL
13 | 3/4 D. X 7/16 | BERYLLIUM COPPER | 1
12 | .250 D. X .218 | TEXTOLITE # 1422 | 1
11 | 5/8 D. X 9/16 | ALUM. ALLOY | 61 S-T | 1
10 | .020 D. | STEEL MUSIC WIRE | "
9 | .078 D. X .070 | BRASS 1/2 H. | 46 B 6 | 2
8 | 7/8 D. X 1 | ALUM. ALLOY | 61 S-T | 1
7 | .593 D. X .201 | BRASS 1/2 H. | 46 B 6 | 1
6 | .375 D. X .250 | BERYLLIUM COPPER | 1
5 | .609 D. X .004 | TEFLON | 1
4 | .375 D. X .156 | TEXTOLITE # 1422 | 1
3 | 3/4 D. X .390 | ALUM. ALLOY | 61 S-T | 1
2 | 1/2 D. X .375 | ALUM. ALLOY | 61 S-T | 1
1 | WELLMENT | - | 1
CRYSTAL HOLDER ASSEMBLY | - | 1
DETAIL NO. | DESCRIPTION | MATERIAL SPECIFICATIONS | NO. REQ'D.
TOLERANCES UNLESS OTHERWISE SPECIFIED: DECIMAL DIMENSIONS = ± .005; FRACTIONAL DIMENSIONS = ± 1/64; ANGLE DIMENSIONS = ± 1°; DIMENSIONS IN INCHES
REFERENCE DRAWINGS
SECURITY CLASSIFICATION: UNCLASSIFIED
DO NOT SCALE DRAWINGS
FINISH 0 ± 32" 3/64 ± 1/2
SIGNATURES | DATE
DESIGN G.K. 9/11
DRAWN R.F. 9/11
CHECKED 9/11/62
UNIT 9/11/62
ENGINEER 9/11/62
ENGIN. 9/11/62
NAVAL RESEARCH LABORATORY WASHINGTON 25, D. C.
CRYSTAL HOLDER ASSEMBLY FOR 3/16 I.D. X 3/8 I.D. WAVE GUIDE
SCALE NOTED
FOR EXPERIMENTAL FABRICATION ONLY
RA 40 D 266 A
SHEET 1 OF 2

Figure 14

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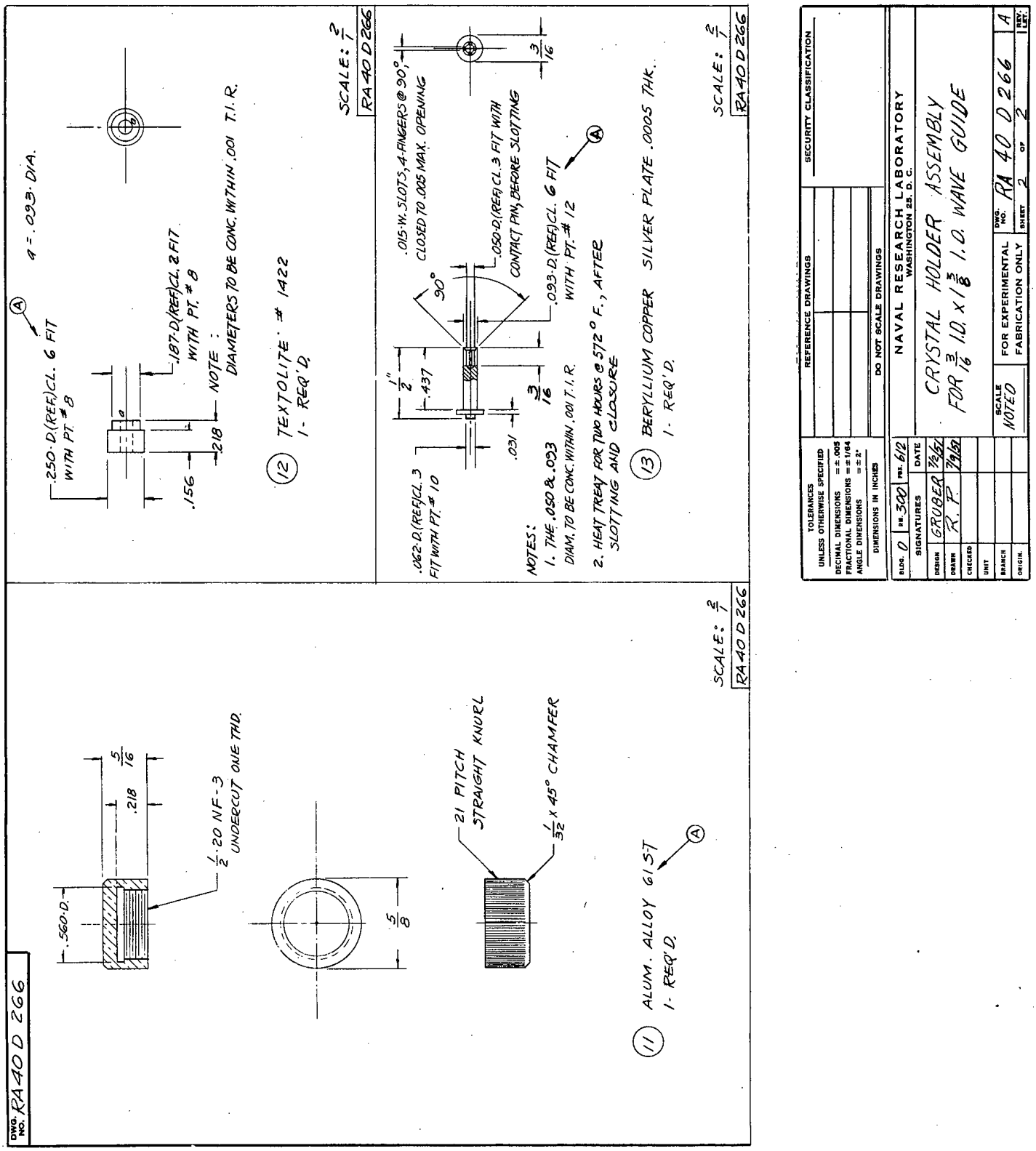

Figure 15

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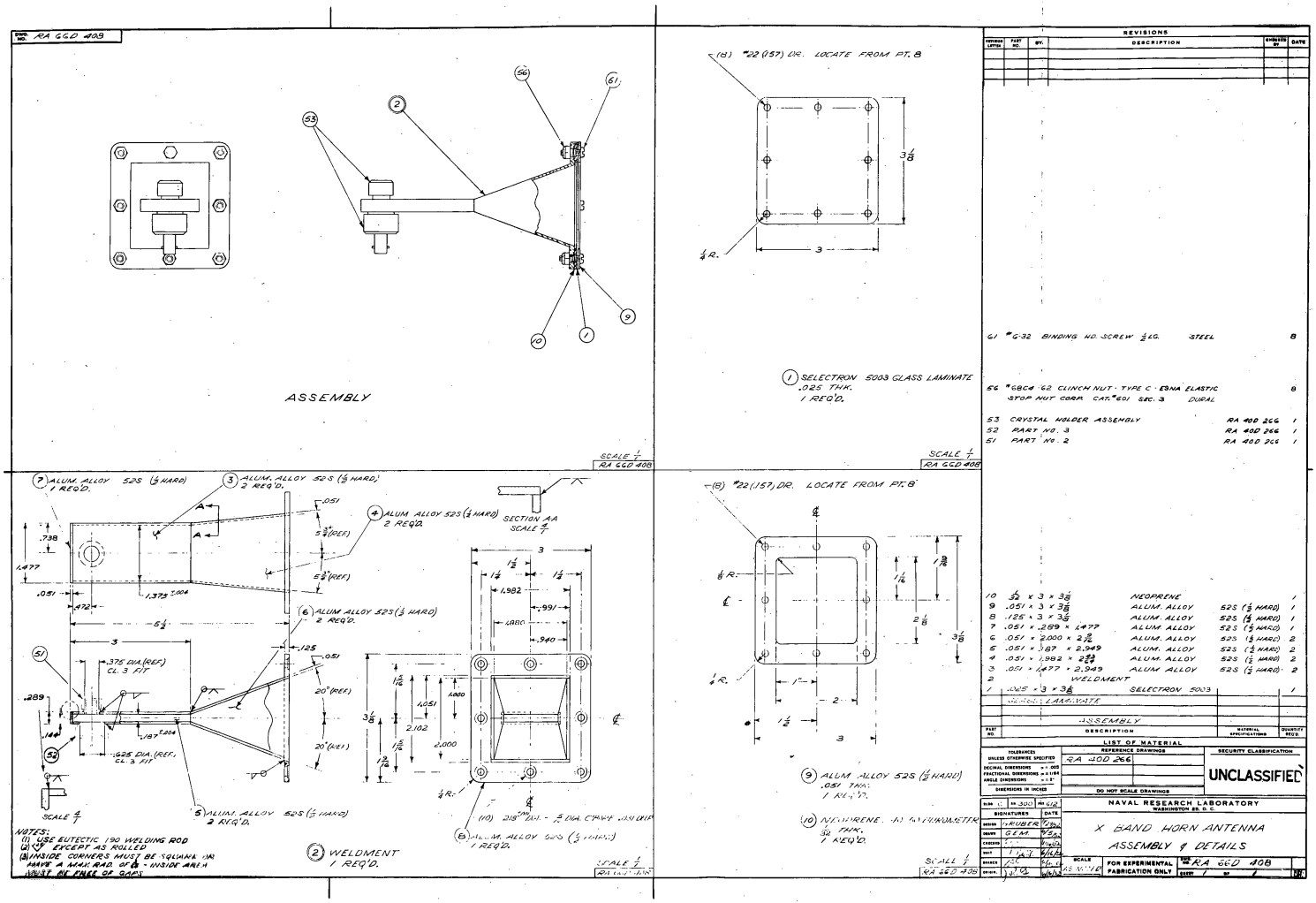
DWG. NO. RA 66D 408
ASSEMBLY
SCALE 1/1
RA 66D 408
(1) SELECTRON 5003 GLASS LAMINATE .025 THK. 1 REQ'D.
(18) #22 (.157) DR. LOCATE FROM PT. B
REVISIONS
DESCRIPTION
61 #6-32 BINDING HD. SCREW ½ LG. STEEL 8
56 #6BC4-62 CLINCH NUT - TYPE C - ESNA ELASTIC STOP NUT CORP. CAT. #601 SEC. 3 DURAL 8
53 CRYSTAL HOLDER ASSEMBLY RA 400 266 1
52 PART NO. 3 RA 400 266 1
51 PART NO. 2 RA 400 266 1
10 .051 x 3 x 3⅜ NEOPRENE 1
9 .051 x 3 x 3⅜ ALUM. ALLOY 525 (¼ HARD) 1
8 .125 x 3 x 3⅜ ALUM. ALLOY 525 (¼ HARD) 1
7 .051 x .269 x 1.477 ALUM. ALLOY 525 (½ HARD) 1
6 .051 x 2.000 x 2⅞ ALUM. ALLOY 525 (¼ HARD) 2
5 .051 x 1.187 x 2.349 ALUM. ALLOY 525 (½ HARD) 2
4 .051 x 1.982 x 2⅞ ALUM. ALLOY 525 (¼ HARD) 2
3 .051 x 1.477 x 2.349 ALUM. ALLOY 525 (½ HARD) 2
2 WELDMENT
1 .005 x 3 x 3⅜ SELECTRON 5003 1
GLASS LAMINATE
ASSEMBLY
PART NO. DESCRIPTION MATERIAL SPECIFICATIONS QUANTITY REQ'D
LIST OF MATERIAL
REFERENCE DRAWINGS
RA 400 266
SECURITY CLASSIFICATION
UNCLASSIFIED
TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL DIMENSIONS ± .005
FRACTIONAL DIMENSIONS ± 1/64
ANGLE DIMENSIONS ± 1°
DIMENSIONS IN INCHES
DO NOT SCALE DRAWINGS
NAVAL RESEARCH LABORATORY
WASHINGTON 25, D. C.
SIGNATURES DATE
DRAWN G.E.M. 9/24/62
CHECKED 9/24/62
UNIT 9/24/62
ENGR 9/24/62
DESIGN 9/24/62
X BAND HORN ANTENNA
ASSEMBLY & DETAILS
SCALE FOR EXPERIMENTAL FABRICATION ONLY
DWG. NO. RA 66D 408
SHEET 1 OF 1
(7) ALUM. ALLOY 525 (½ HARD) 1 REQ'D.
(3) ALUM. ALLOY 525 (½ HARD) 2 REQ'D.
(4) ALUM. ALLOY 525 (¼ HARD) 2 REQ'D.
(6) ALUM. ALLOY 525 (¼ HARD) 2 REQ'D.
SECTION AA SCALE 4/1
.375 DIA. (REF.) CL. 3 FIT
.625 DIA. (REF.) CL. 3 FIT
(5) ALUM. ALLOY 525 (½ HARD) 2 REQ'D.
SCALE 4/1
NOTES:
(1) USE EUTECTIC 190 WELDING ROD
(2) 63 EXCEPT AS ROLLED
(3) INSIDE CORNERS MUST BE SQUARE OR RADII A MAX. OF .03 - INSIDE RADII MUST BE EQUAL OR LESS
(2) WELDMENT 1 REQ'D.
SCALE 1/1
RA 66D 408
(18) #22 (.157) DR. LOCATE FROM PT. B
(9) ALUM. ALLOY 525 (¼ HARD) .051 THK. 1 REQ'D.
(10) NEOPRENE .051 THK. 1 REQ'D.
SCALE 1/1
RA 66D 408

UNCLASSIFIED

Figure 16

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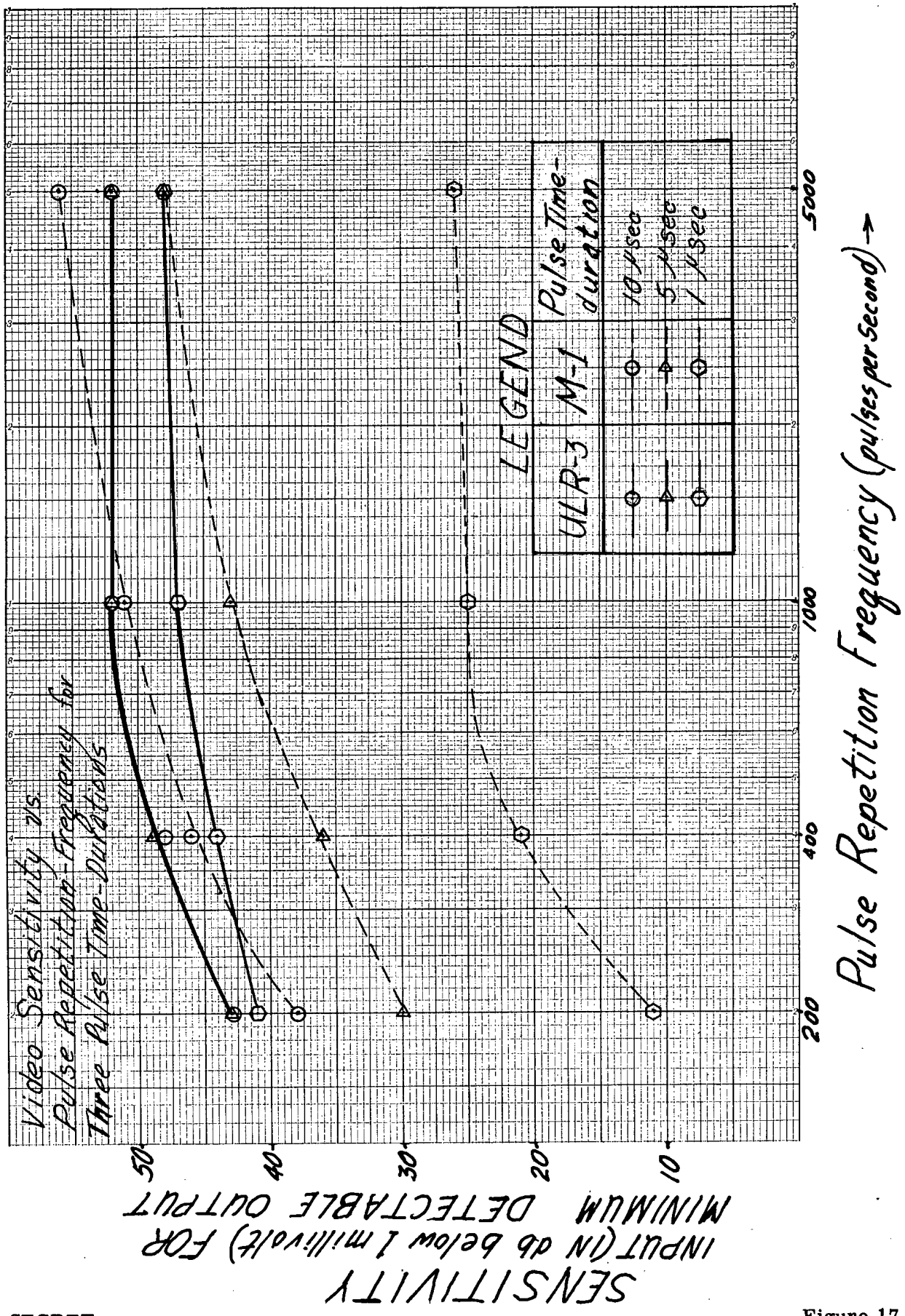

Figure 17

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SECRET

SECRET

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